Groundwater Availability within the Salton Sea Basin

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Project Background

- Salton Sea is the largest lake in area in California
- Overall basin occupies portions of 4 California counties and northern Baja California, Mexico
- Imperial County one of the most productive agricultural regions in US, largely due to imported water
- Agricultural and urban (San Diego) water interests threatened by reduced Colorado River water allocations to California
- Ongoing ecological degradation of Salton Sea further complicates this equation

Why Groundwater?

- Groundwater suggested as an alternative source for water demands in Salton Sea basin, **yet** …
- Agriculture heavily dependent on imported Colorado River water, not groundwater;
- Groundwater in the southern basin not heavily used because of quality and inaccessibility concerns … **yet**
- Groundwater is widely produced in northern part of the basin.
- **Thus**: A need for an integrated and continuing assessment of **groundwater availability** in the basin as a whole was identified…

Why LLNL?

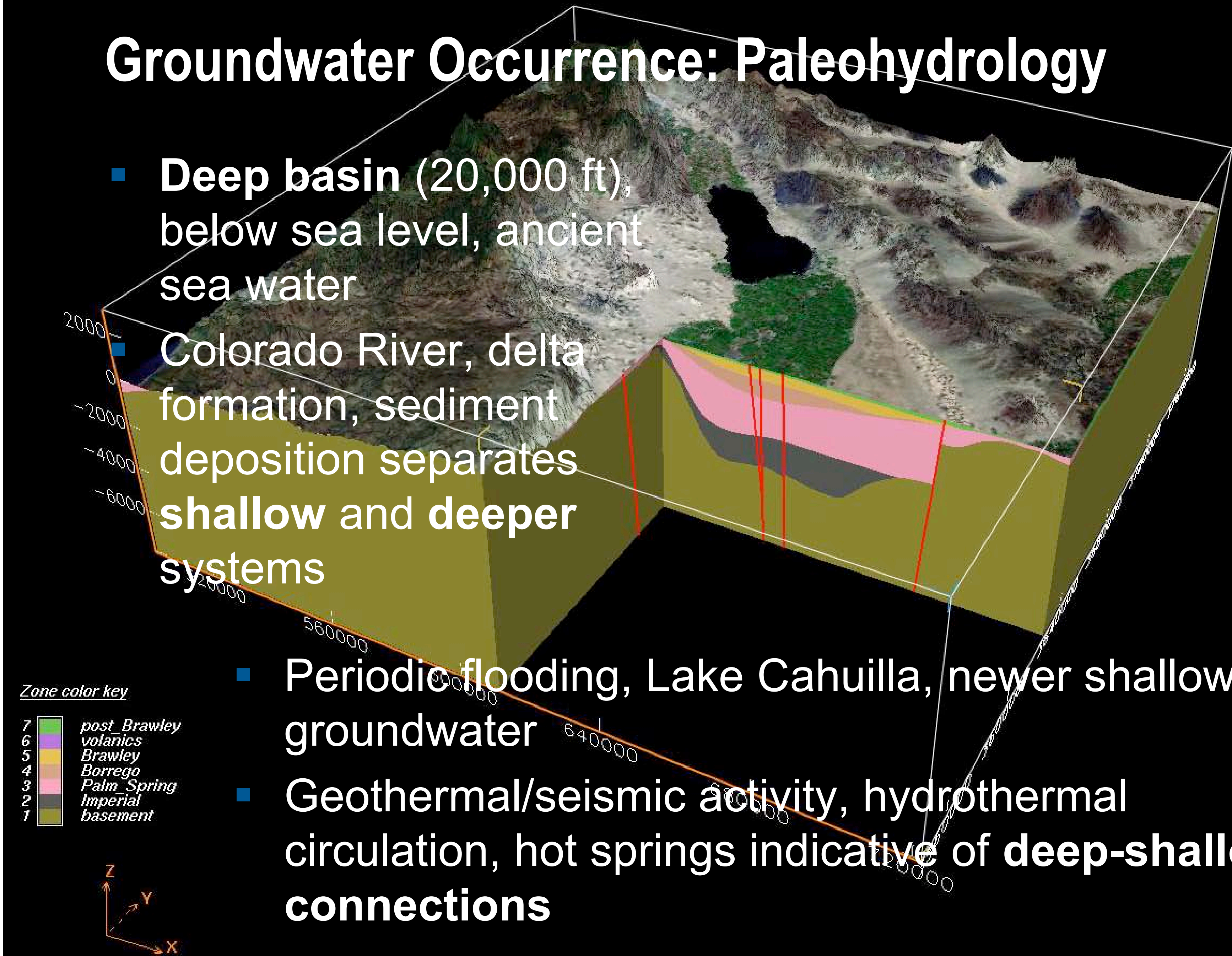
- Project sponsored by Congress through US Bureau of Reclamation
- Laboratory disconnected from contentious arena of multiple users, agencies, and agendas:
- Laboratory can offer unique or well-developed S&T capabilities for water resource management and assessment activities:
- Complex, integrated and secure GIS database development tools and experience
- Isotopic characterization and assessment
- Advanced groundwater, surface water, and climate model development and application

Groundwater Availability: Four Key Concepts

- **Volume** and **capacity** of groundwater basin
- **Producibility** of groundwater (permeability, depth)
- **Quality** of groundwater (as for specific uses)
- **Renewability** of groundwater supply (recharge)

Groundwater Occurrence: Paleohydrology

- **Deep basin** (20,000 ft), below sea level, ancient sea water
- Colorado River, delta formation, sediment deposition separates **shallow** and **deeper** systems
- Periodic flooding, Lake Cahuilla, newer shallow groundwater
- Geothermal/seismic activity, hydrothermal circulation, hot springs indicative of **deep-shallow connections**



Groundwater Occurrence: Today

- **Potentially as high as 4.5 to 6.5 BAF** in basin as a whole, **yet …**
- Most confined to the deeper system where quality is **poor**, producibility is **low**, natural recharge **not well demonstrated**
- **Annual recharge** in shallow system dominated by agriculture returns, canal losses, ASR operations in Coachella Valley. Precipitation is smaller factor.
- Basin-wide average precipitation ~ **2.5 MAF/y**
- Springs, deeper recharge (?) primarily located at western and northern perimeters, where precipitation concentrated
- Potential areas of **new production** in Imperial Valley limited to West Mesa areas and new ASR operations

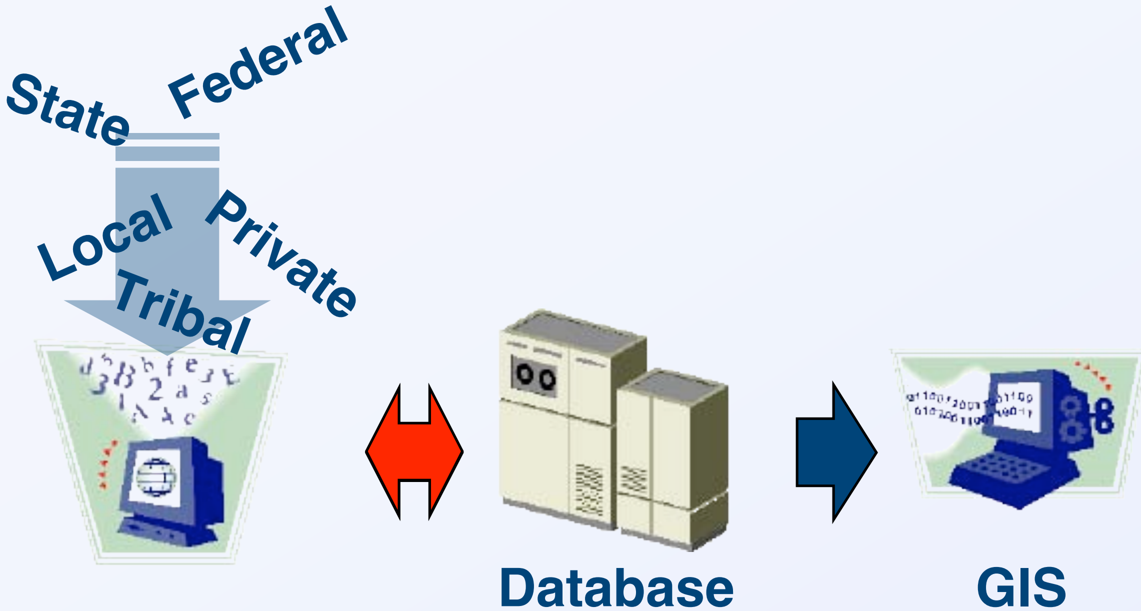
Project objectives developed with USBR

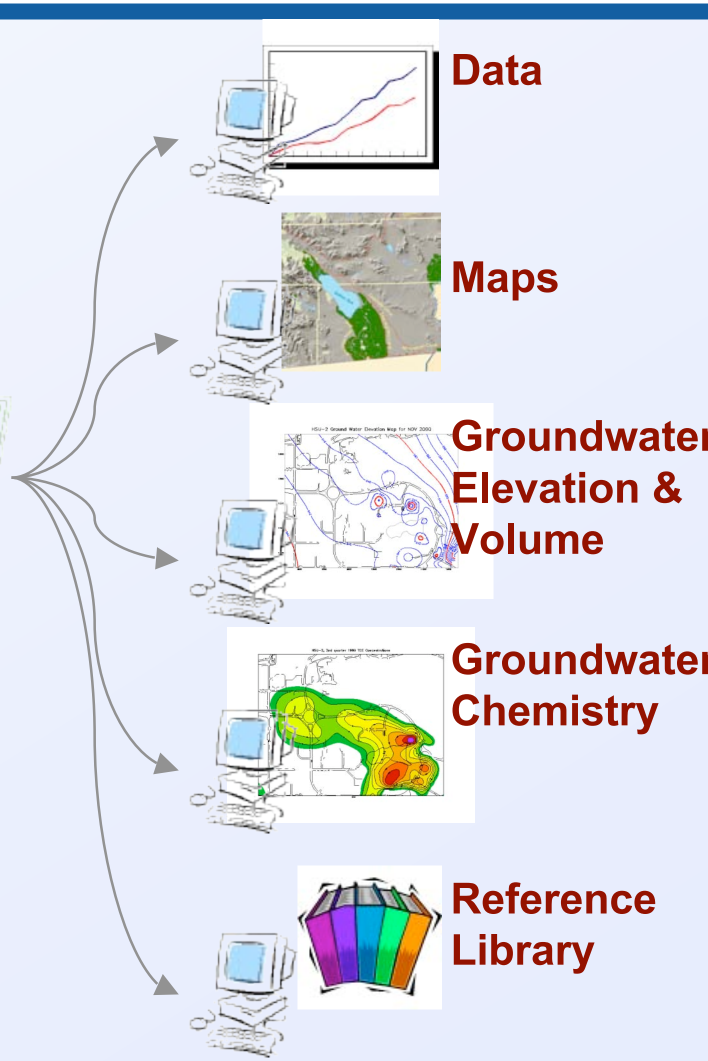
- **Establish** and **implement a process** to acquire, assemble, organize, integrate, and make accessible as much of the existing and relevant data and interpretive information as possible that relate to quantifying groundwater availability in the Salton Sea basin.
- **Develop** and **advance** one or more new data acquisition and interpretation activities related to understanding groundwater availability in the Salton Sea basin.
- **Utilize results** to assess potential new areas or means of production
- Strive to make all products "living" for **continued future use** and **improvement.**

Project objectives developed with USBR

- **Integrated Database Development:** Design and populate two web-based hierarchical databases for groundwater, related hydrogeologic data, and literature, covering the entire basin, including a dynamically linked Geographic Information System (GIS)
- **Isotopic Characterization**: Collect and interpret new isotopic-based data related to groundwater source, age, and quality in the East Mesa area, as a means to better characterize flow in a region undergoing “artificial recharge” from the All American Canal for 60+ years
- **Groundwater Model**: Develop state-of-the art groundwater model in the Imperial Valley, to, e.g., assess impacts of lining the All American Canal

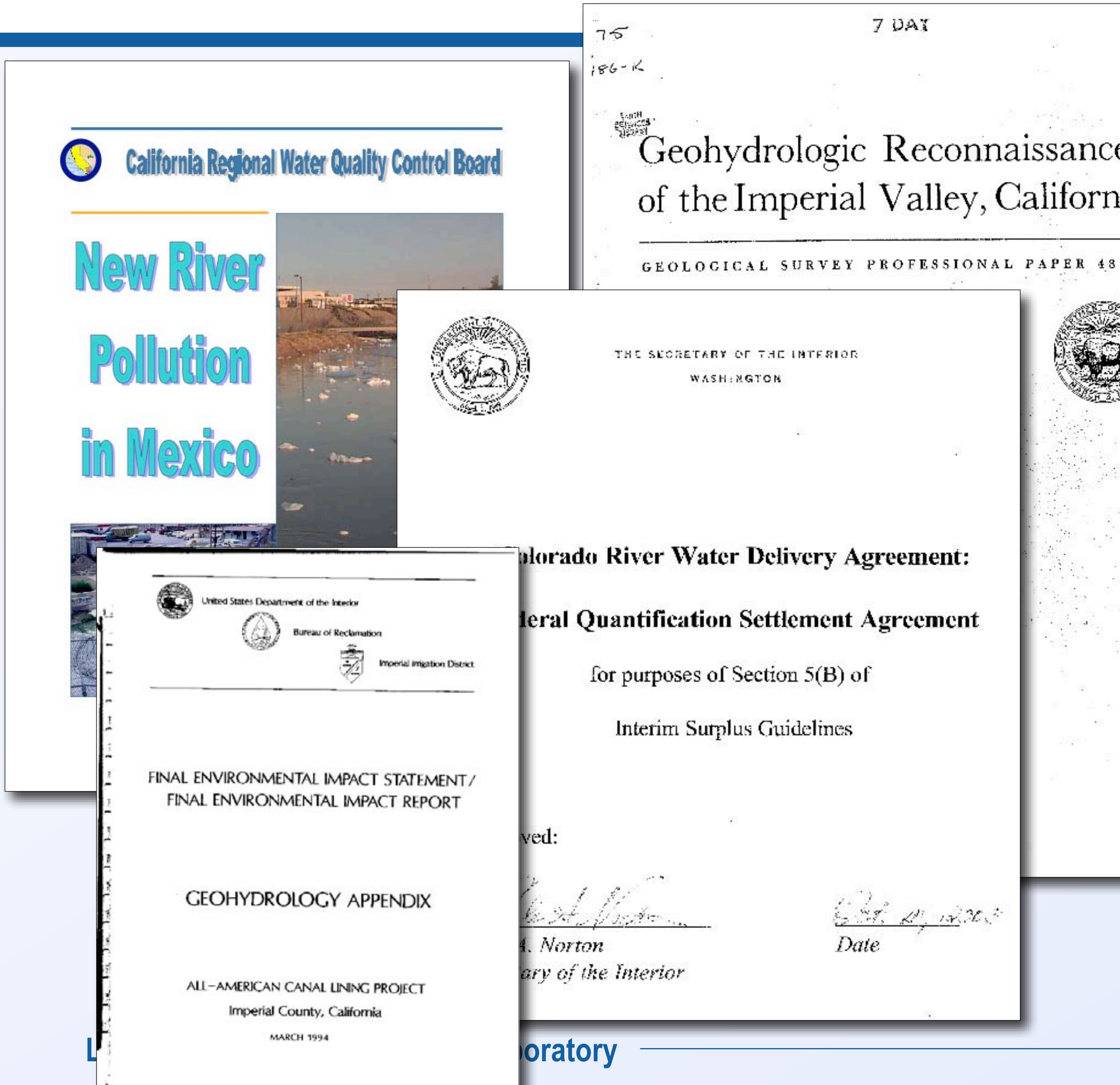
Integrated database and GIS development





The most expensive sample ever collected is the one whose results are never used

300+ reference documents in literature database



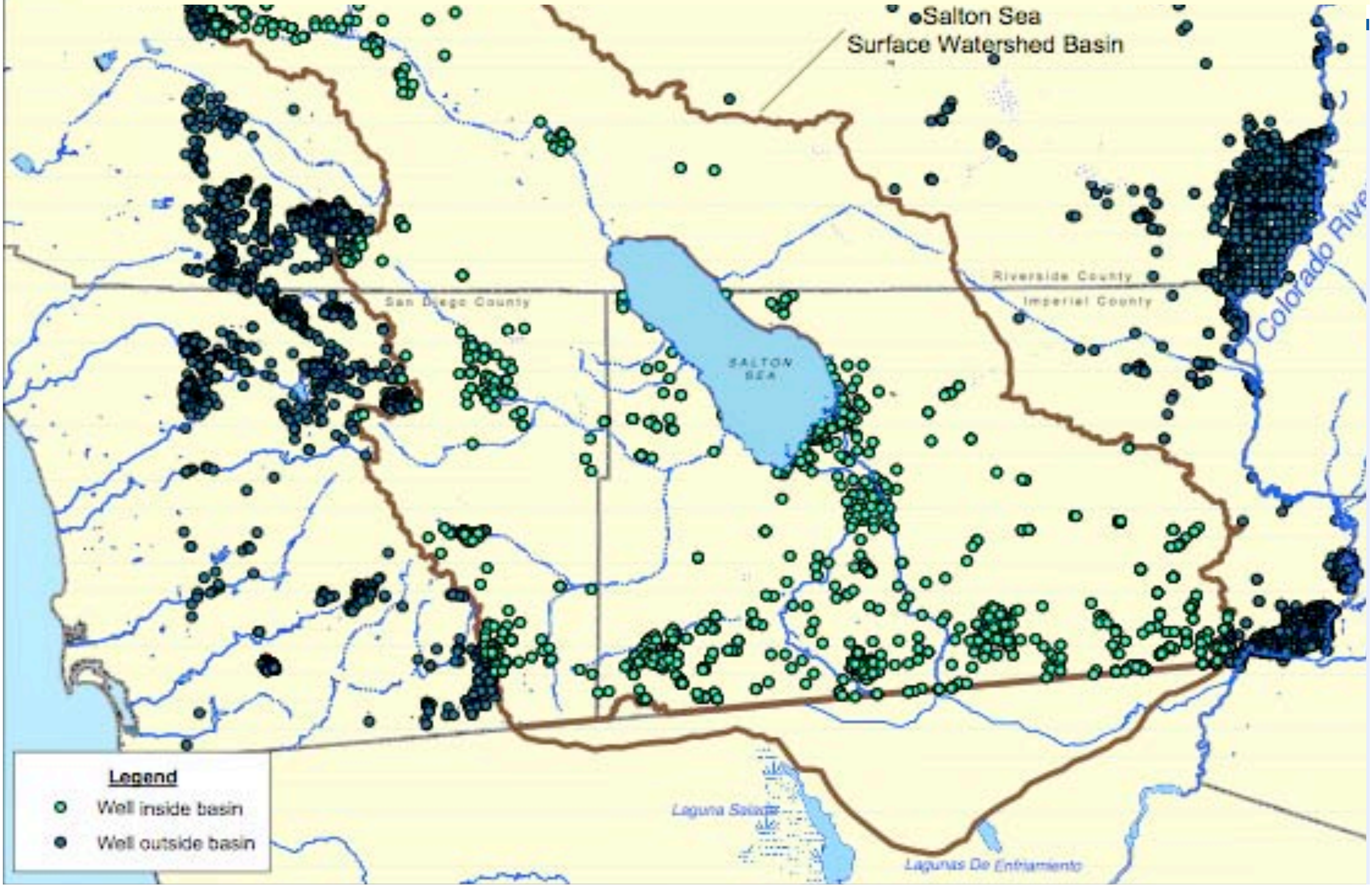
- Colorado River
- Water Supply Issues
- Canal and Irrigation Reports
- Geothermal
- Regional Hydrology
- Regional Geology
- Water Quality
- Groundwater Resource Reports
- Legal Documents
- Ecology
- Salton Sea General Interest
- Modeling
- Mexico

So far, data from 17 agencies used to populate water resources database

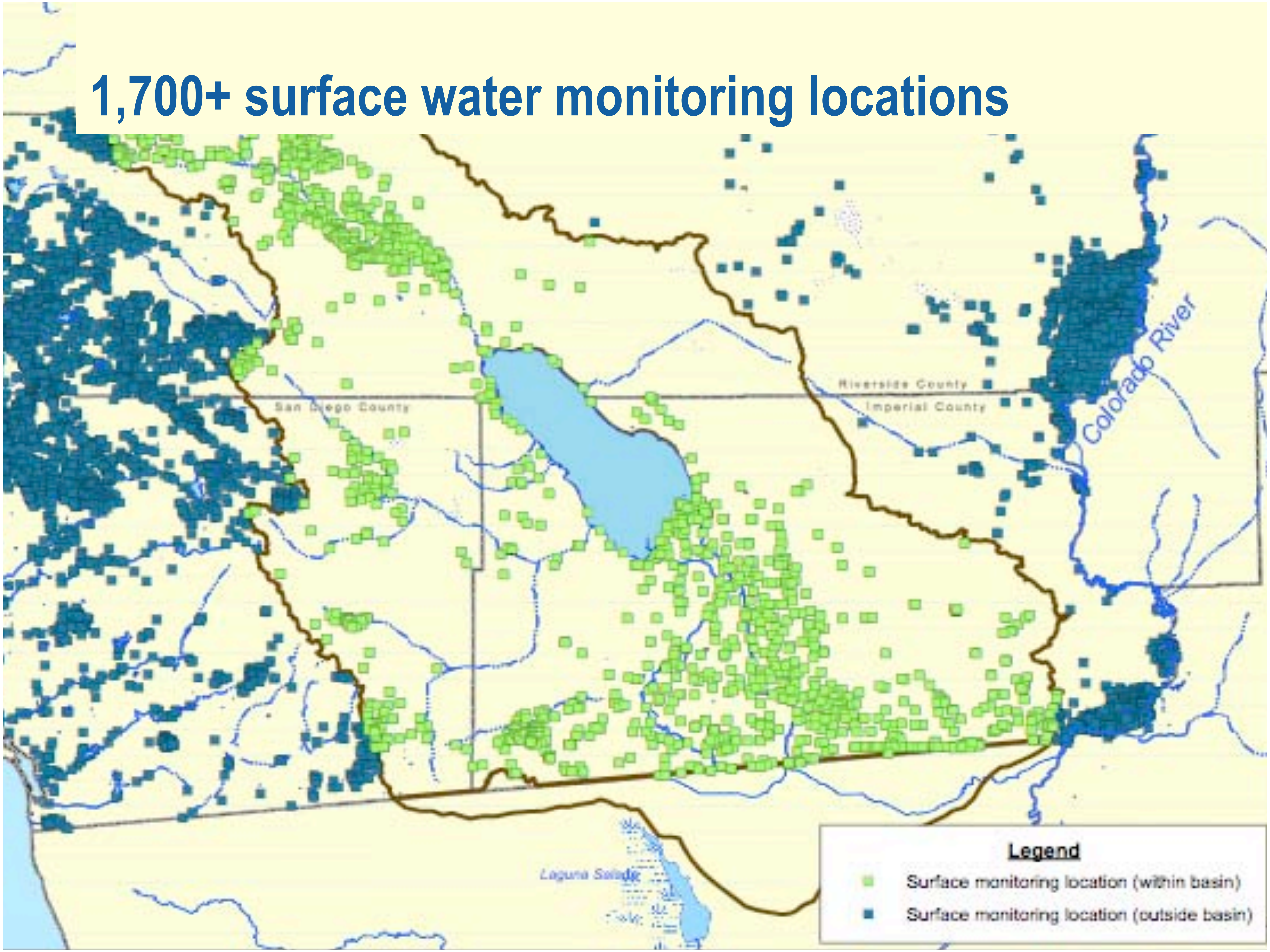
- Efforts focused primarily on **publicly** available data; e.g., USBR, USGS, California DWR, ….
- Efforts focused primarily in **Imperial Valley**
- **Proprietary** sources not yet considered e.g., CVWD, IID, private entities … but easily could be.

- **AGENCY data**
- **GROUNDWATER BASIN data**
- **GEOPHYSICAL data**
- **WELL LOCATION data**
- **WELL CONSTRUCTION data**
- **GROUNDWATER ELEVATION data**
- **GROUNDWATER CHEMISTRY data**
- **GROUNDWATER ISOTOPE data**
- **SURFACE WATER data**
- **CANAL and RIVER data**
- **MEXICO data**
-
- (more)

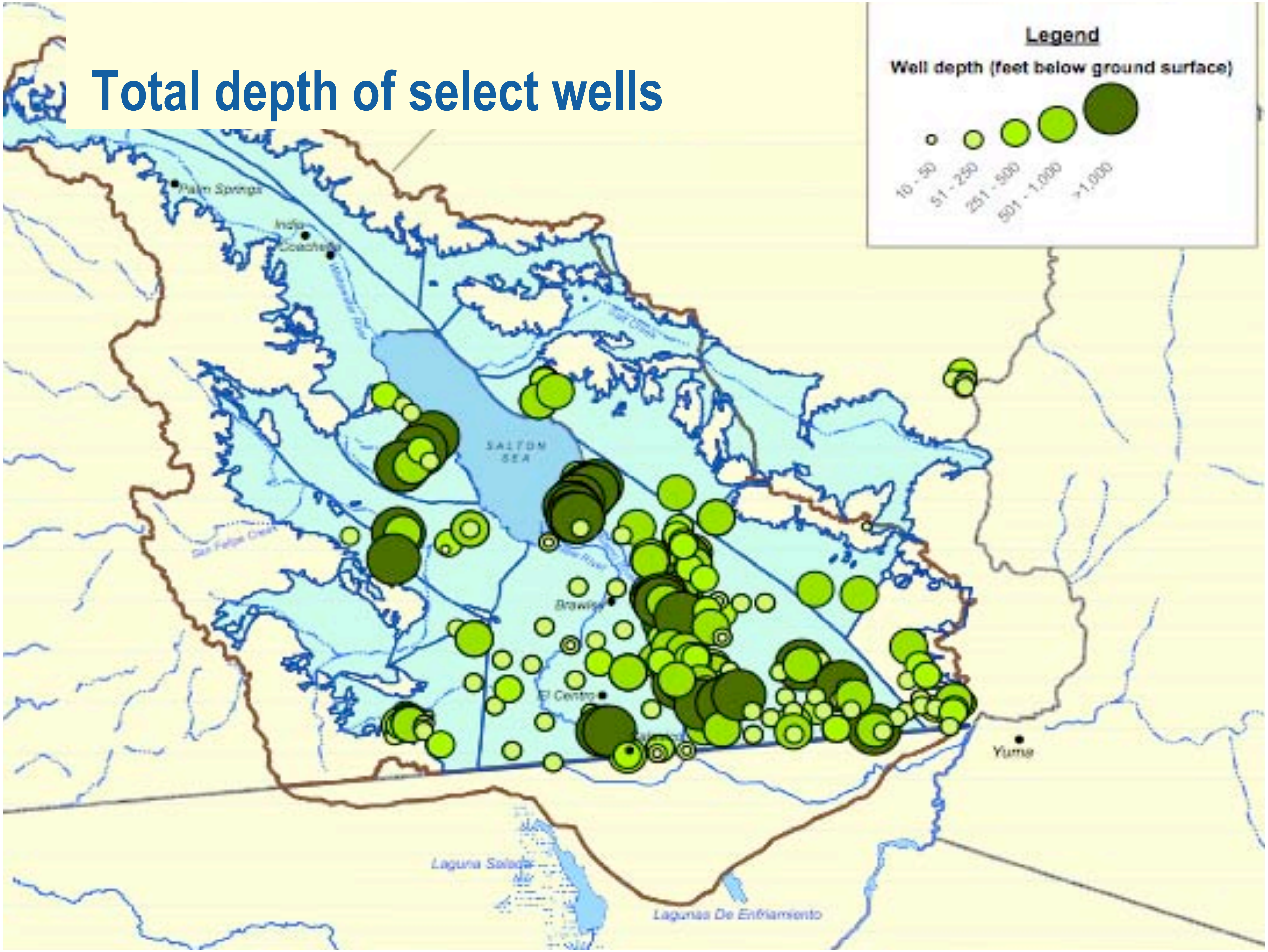
6,000+ water wells in current database



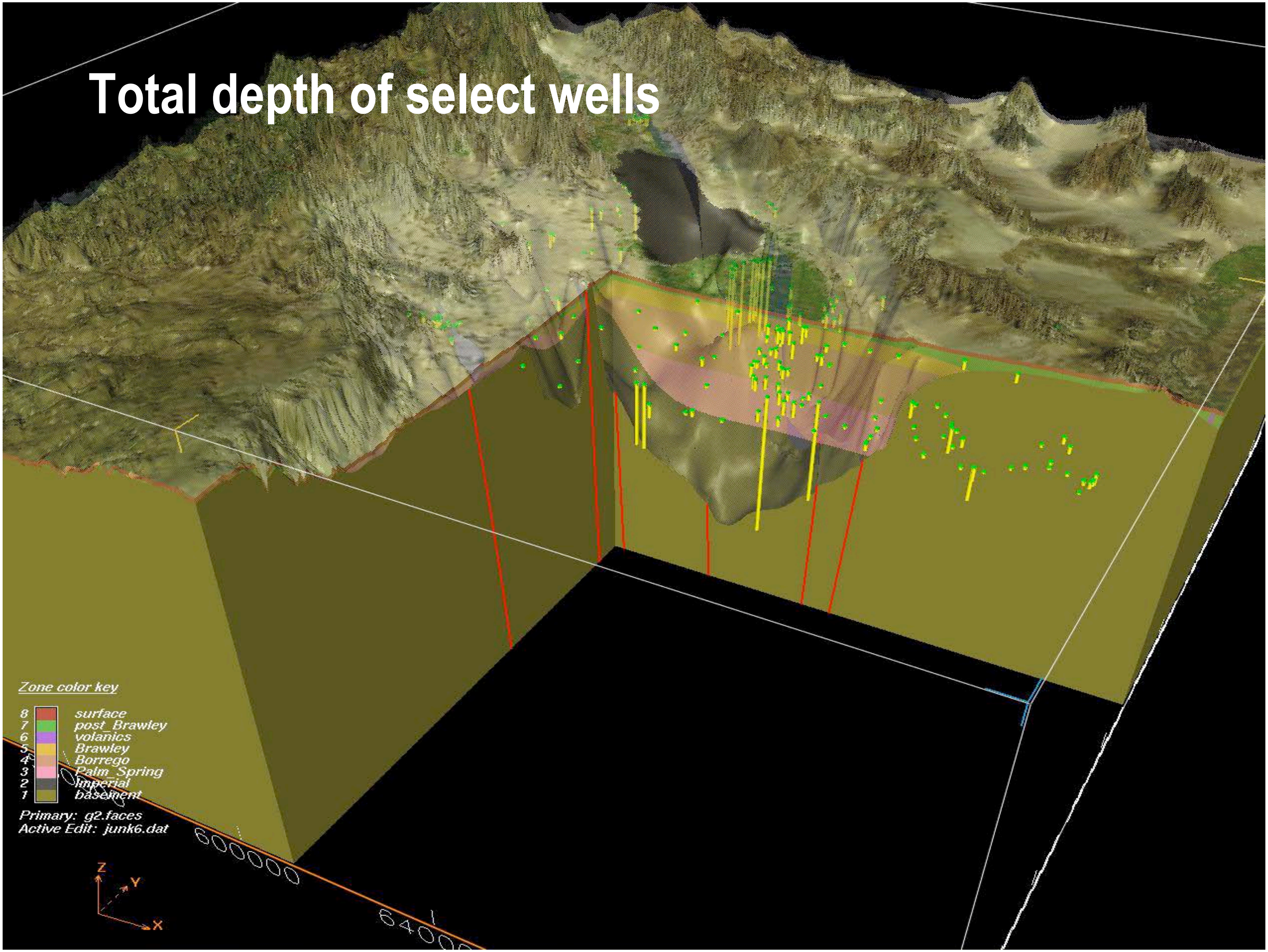
1,700+ surface water monitoring locations



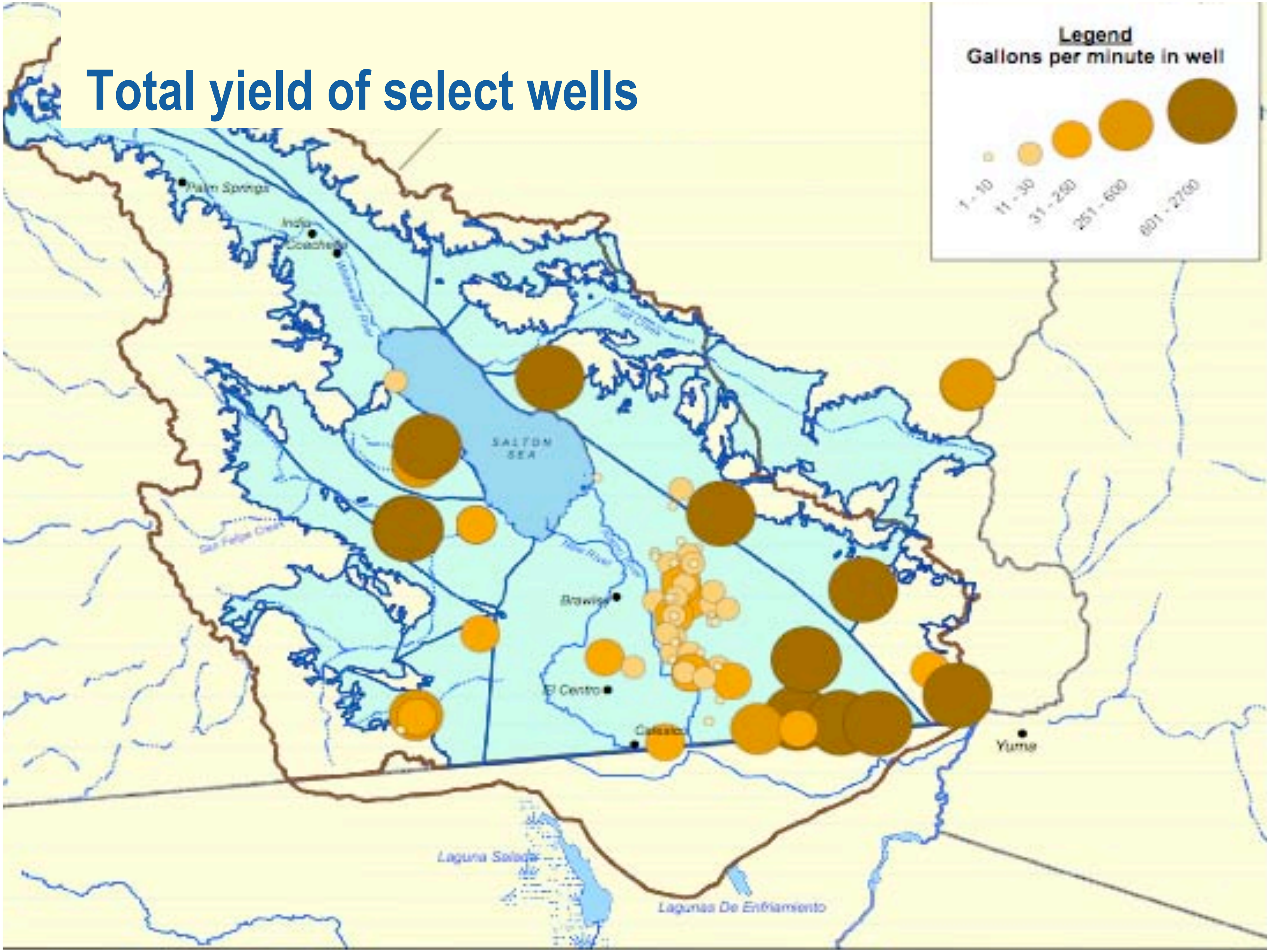
Total depth of select wells



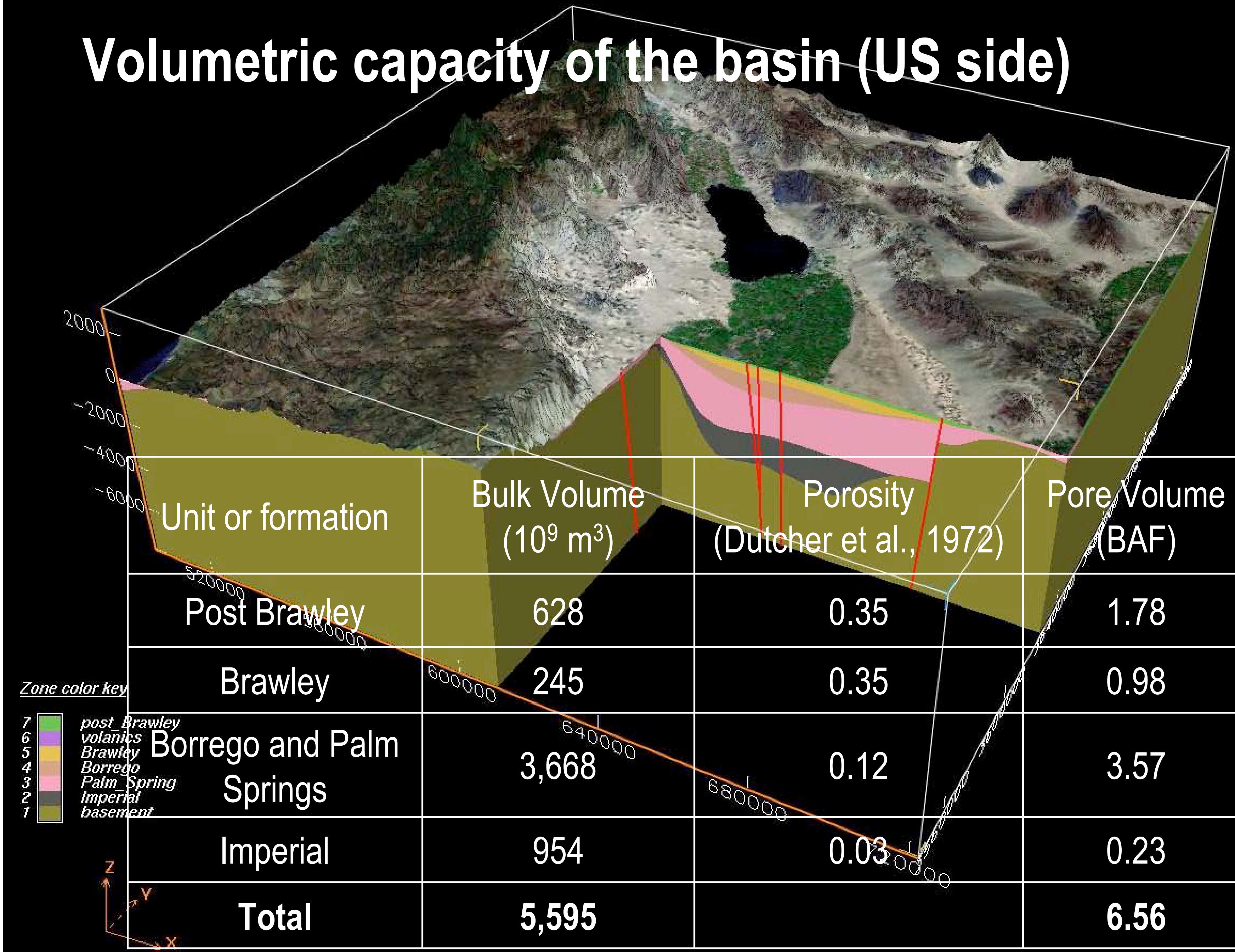
Total depth of select wells



Total yield of select wells



Volumetric capacity of the basin (US side)



Unit or formation	Bulk Volume (10^9 m^3)	Porosity (Dutcher et al., 1972)	Pore Volume (BAF)
Post Brawley	628	0.35	1.78
Brawley	245	0.35	0.98
Borrego and Palm Springs	3,668	0.12	3.57
Imperial	954	0.03	0.23
Total	**5,595**		**6.56**

Annual precipitation concentrated in western and northern mountain areas

- Highest amounts range between 600 and 1,200 mm/y
- Indicative of main precipitation-based recharge areas
- Integrated volume close to 2.5 MAF/y

Dominant precipitation based recharge occurs in western and northern mountain areas

- **Precipitation Excess** (PE) is the difference between Precipitation (P) and Evapotranspiration (ET) at a location, **x**
- Precipitation **recharge** can be estimated from

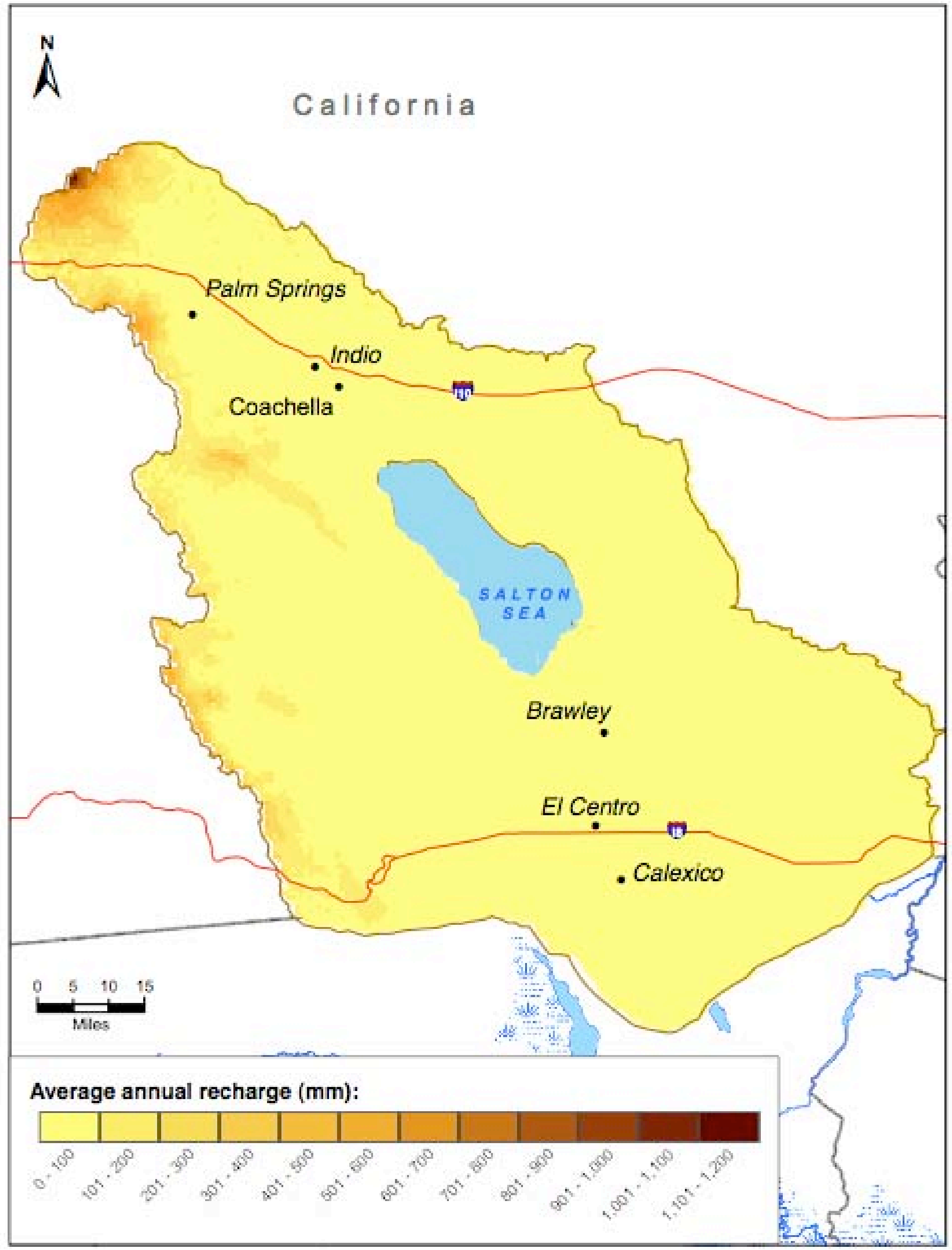
$$R \sim PE = P - ET$$

but does not include effects of **runoff**

$$R(\mathbf{x},t) \sim \int \left\{ P(\mathbf{x}-\mathbf{x}',t) - ET(\mathbf{x}-\mathbf{x}',t) \right\} \cdot w(\mathbf{x}')\,d\mathbf{x}'$$

- In southeast, ET can be greater than P
- Precipitation recharge **dwarfed** by agricultural recharge in irrigated areas

- Total annual PE calculated on a month to month basis
- Monthly data includes P, T, daylight hrs.
- Spatial land use/vegetation data
- Monthly results highest in December - March
- Annual results range from 0 to 900 mm/y



Some typical results of this analysis …

- **Watershed**

  P ~ 2.5 MAF/y
  PE ~ 456,000 AF/y

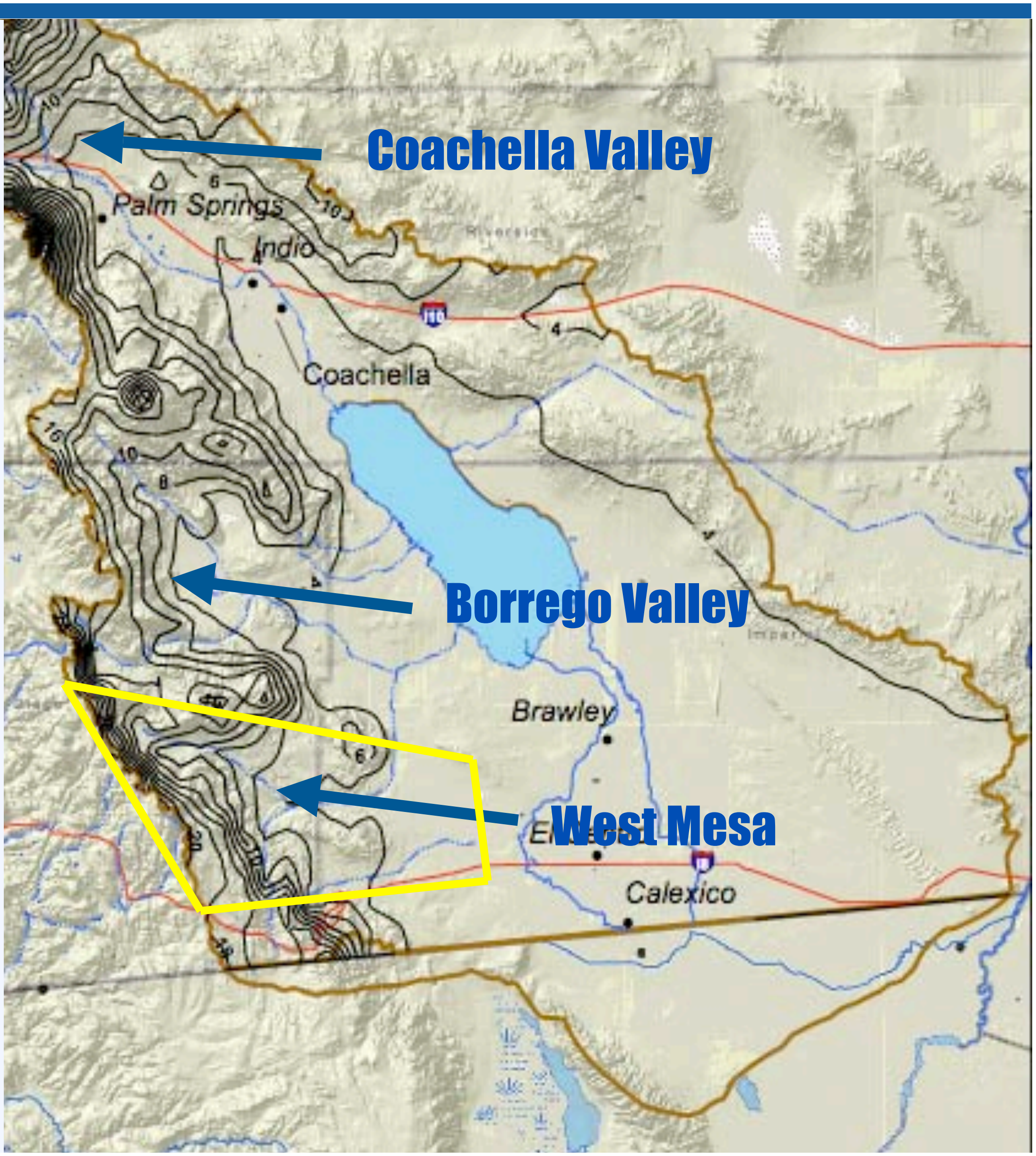
- **Groundwater basins alone**

  PE ~ 45,000 AF/y

- **West Mesa**:

  P ~ 60,000 AF/y
  PE ~ 2,000 AF/y

- Inclusion of runoff will change these numbers

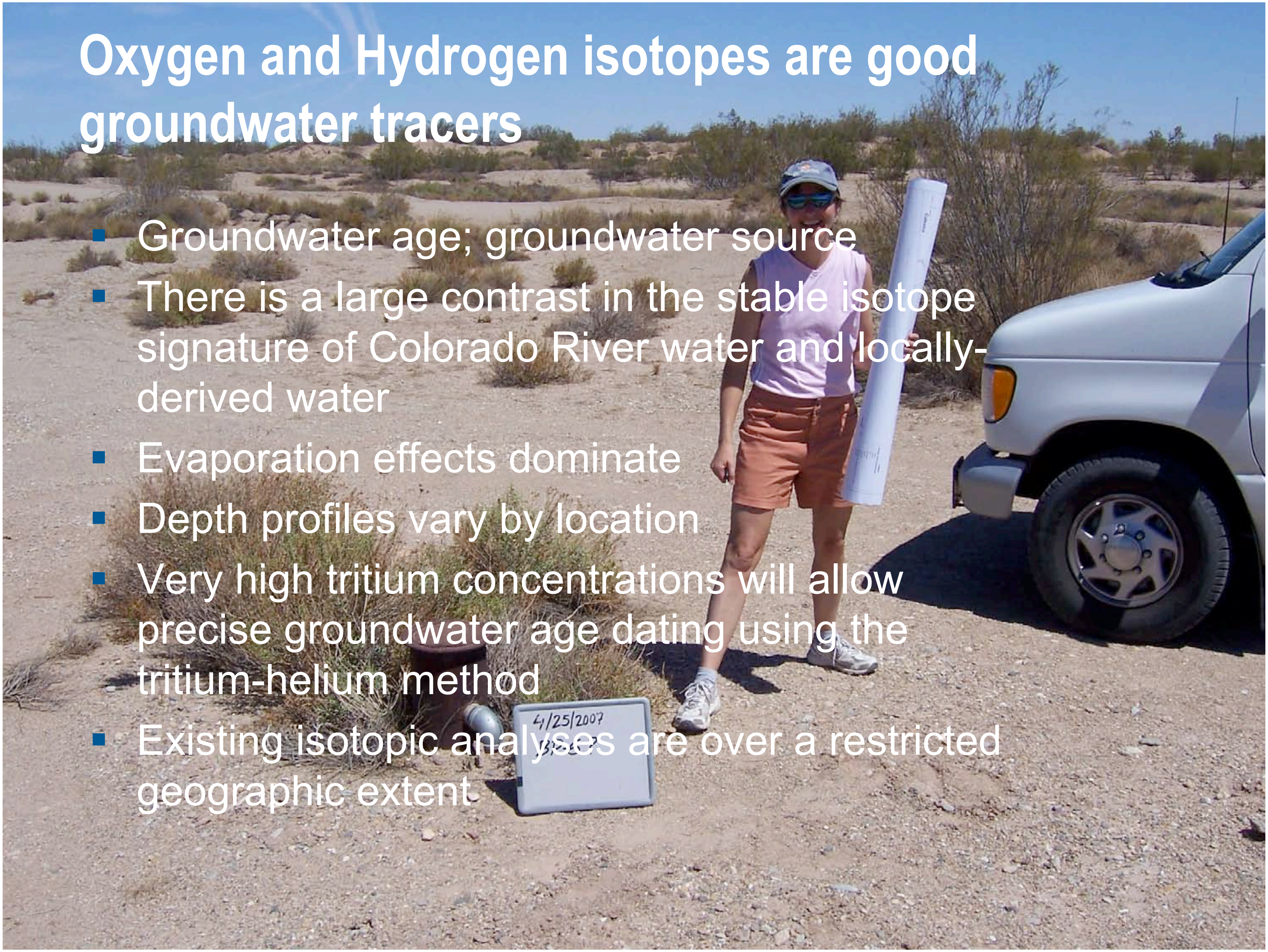


ASR: Promising approach for new groundwater storage in the East Mesa Area?

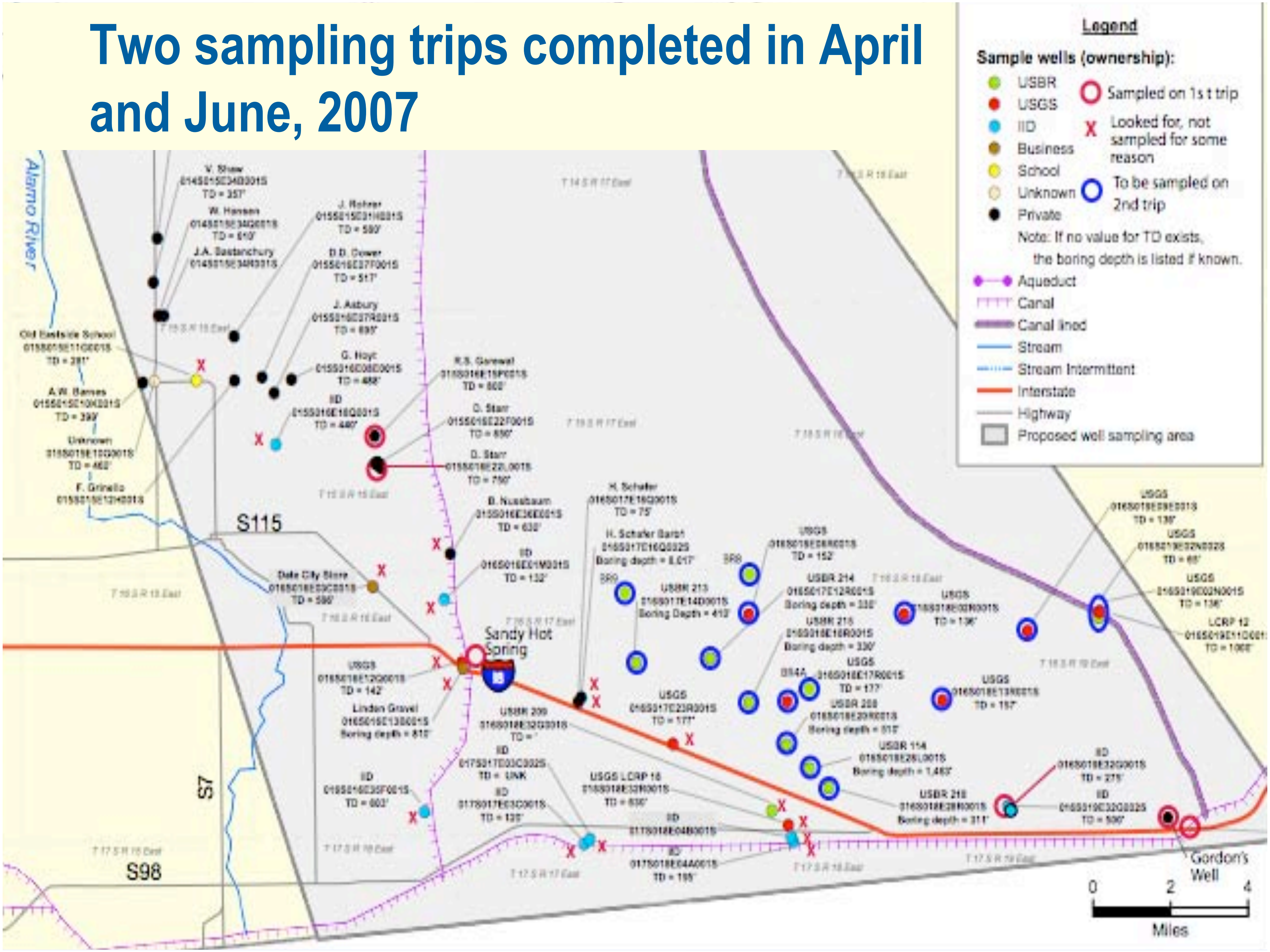
- Aggregate AAC losses ~ 4.9 MAF 1948-1988
- Accrued storage increase (now steady) ~ 0.7 to 1.5 MAF
- Understanding the difference will be critical to ASR design
- Isotopic characterization of East Mesa groundwater provides means to assess nature of “60 year aquifer storage experiment”
- Determine extent of recent recharge from unlined canals
- Delineate losing reaches
- Determine residence time and flow paths of groundwater in ‘mounded’ areas
- Assess water quality changes along recharge pathways

Oxygen and Hydrogen isotopes are good groundwater tracers

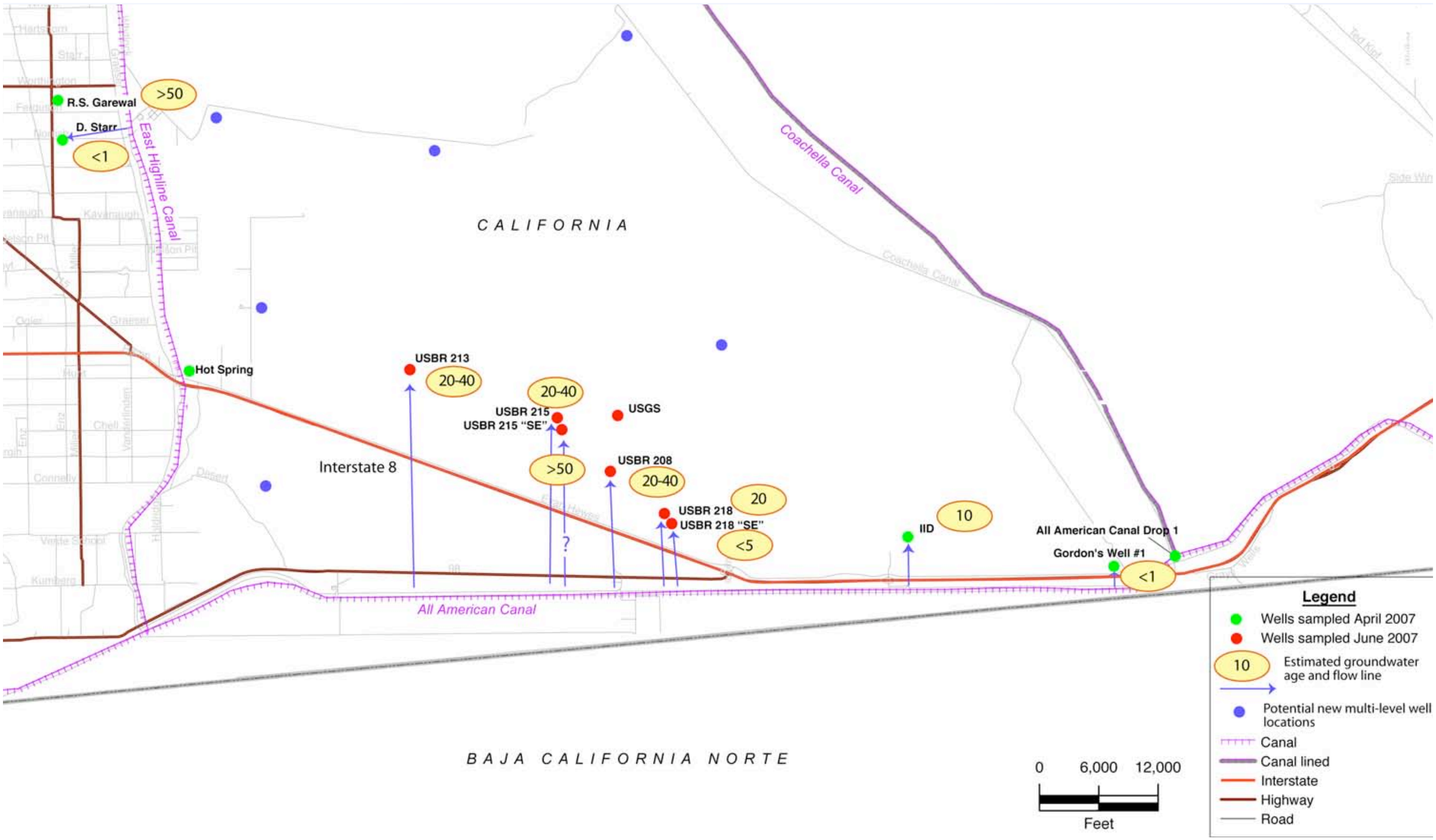
- Groundwater age; groundwater source
- There is a large contrast in the stable isotope signature of Colorado River water and locally-derived water
- Evaporation effects dominate
- Depth profiles vary by location
- Very high tritium concentrations will allow precise groundwater age dating using the tritium-helium method
- Existing isotopic analyses are over a restricted geographic extent



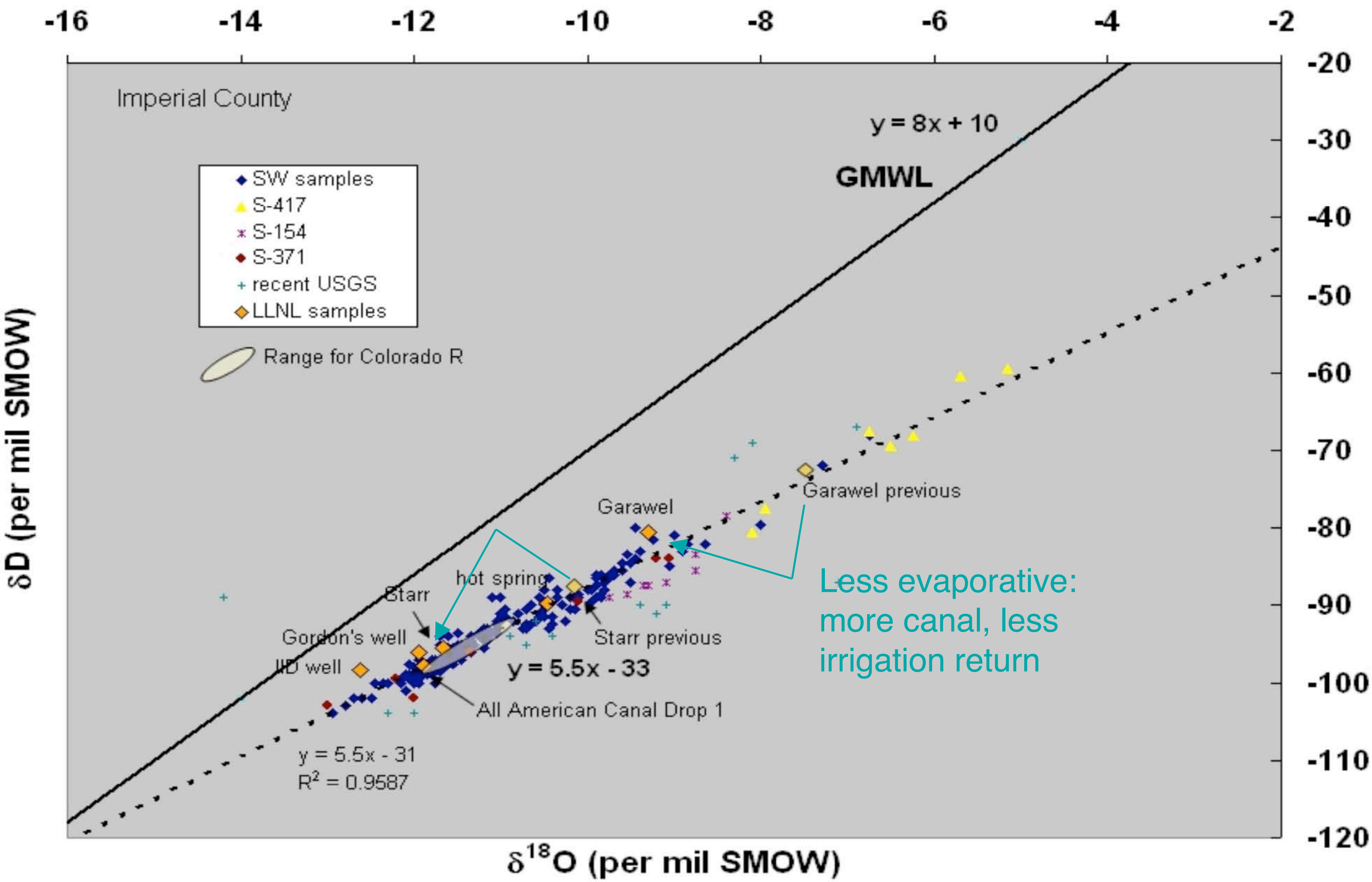
Two sampling trips completed in April and June, 2007



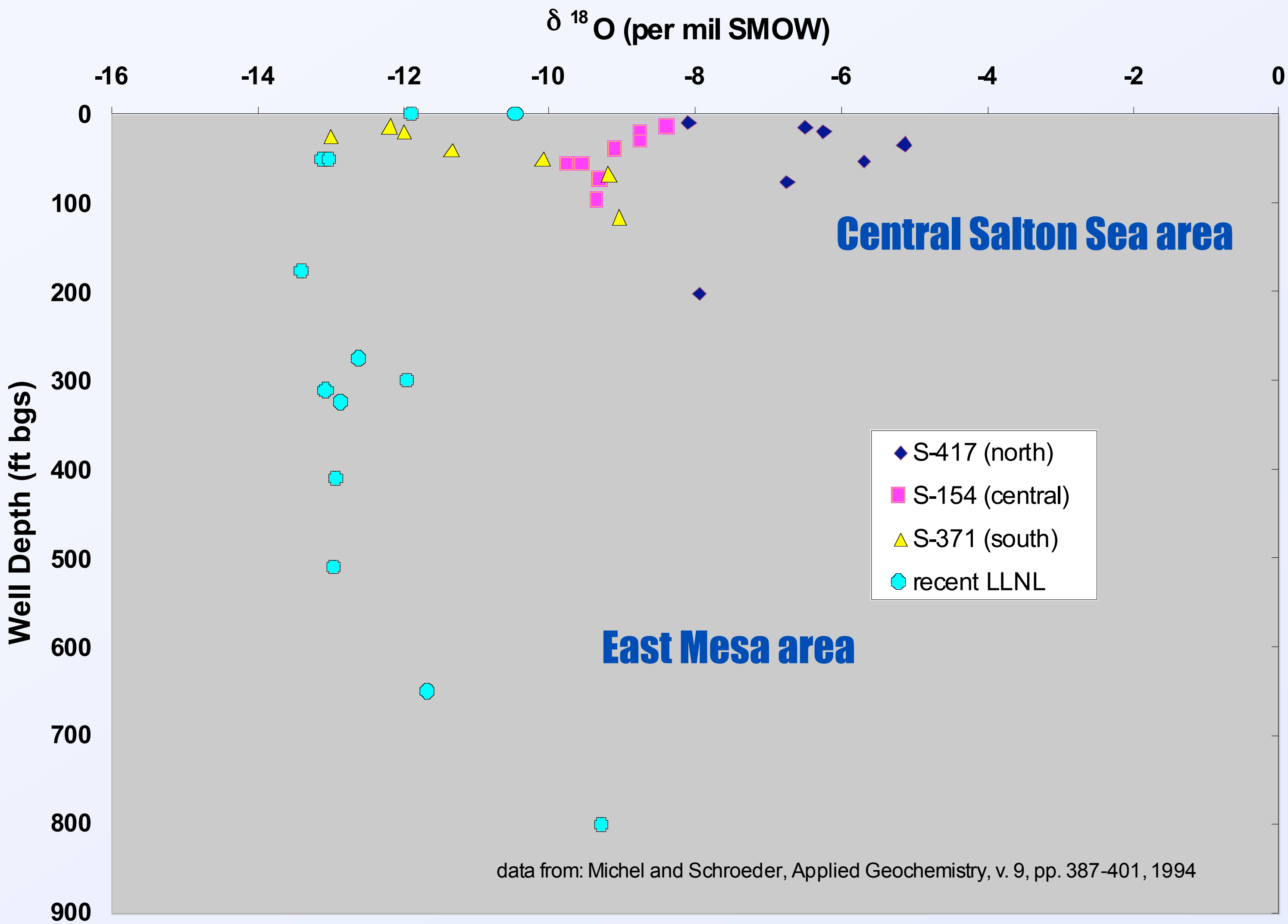
Tritium-based age dates in 10 wells show canal and irrigation influences



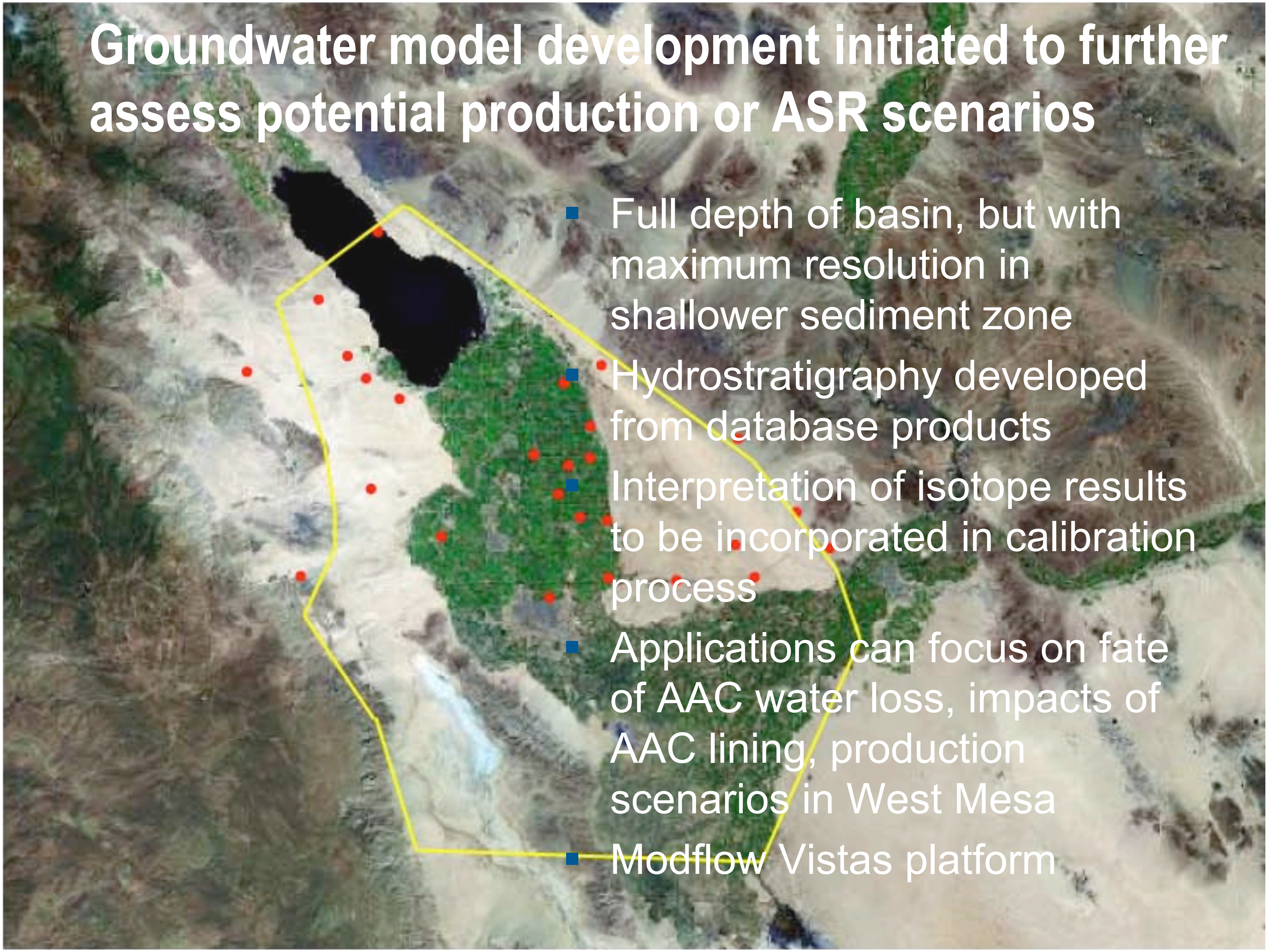
Oxygen and Hydrogen ratios in 12 wells show canal and irrigation influences



Oxygen and Hydrogen ratios indicate deeper penetration of water unaffected by agriculture

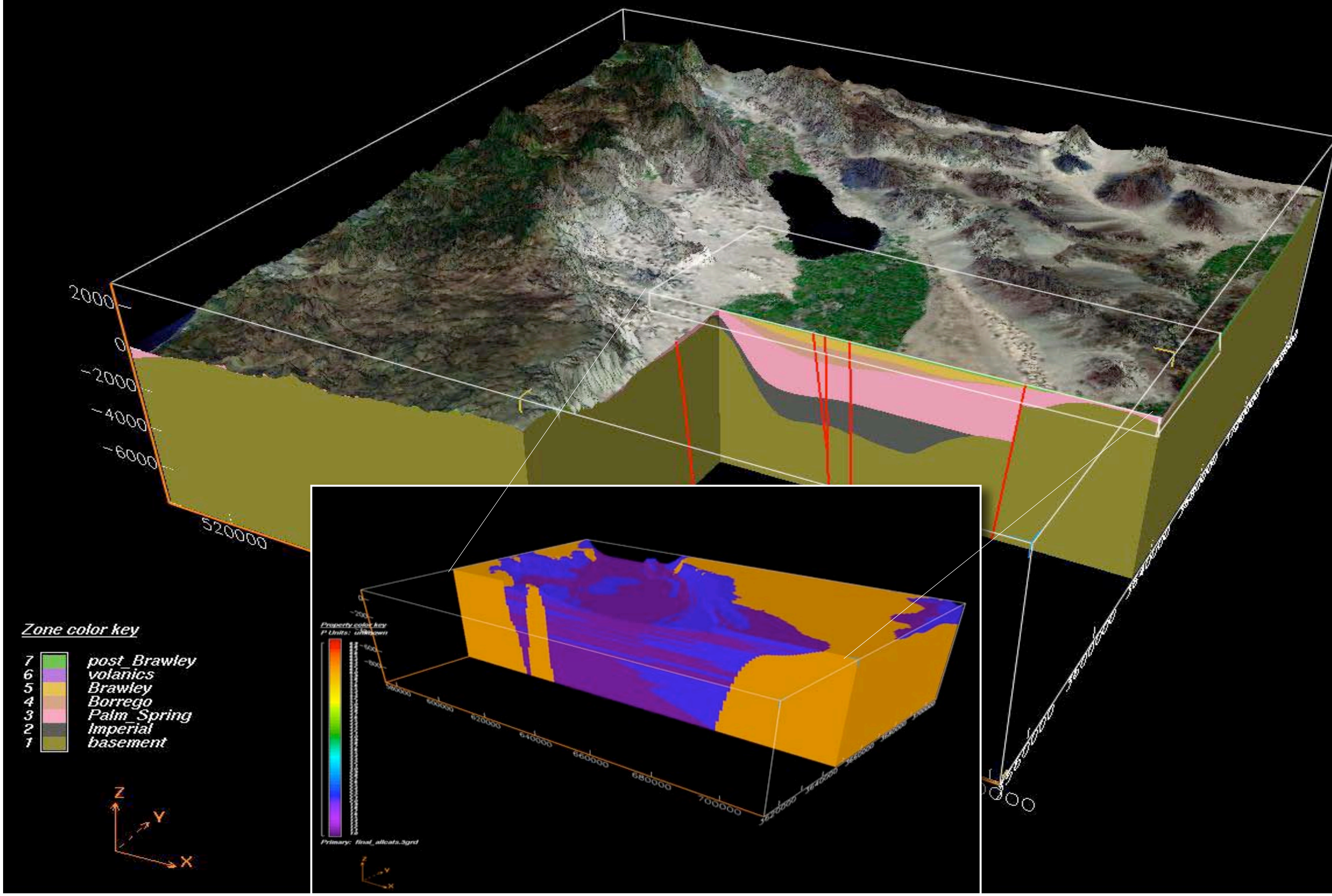


Groundwater model development initiated to further assess potential production or ASR scenarios

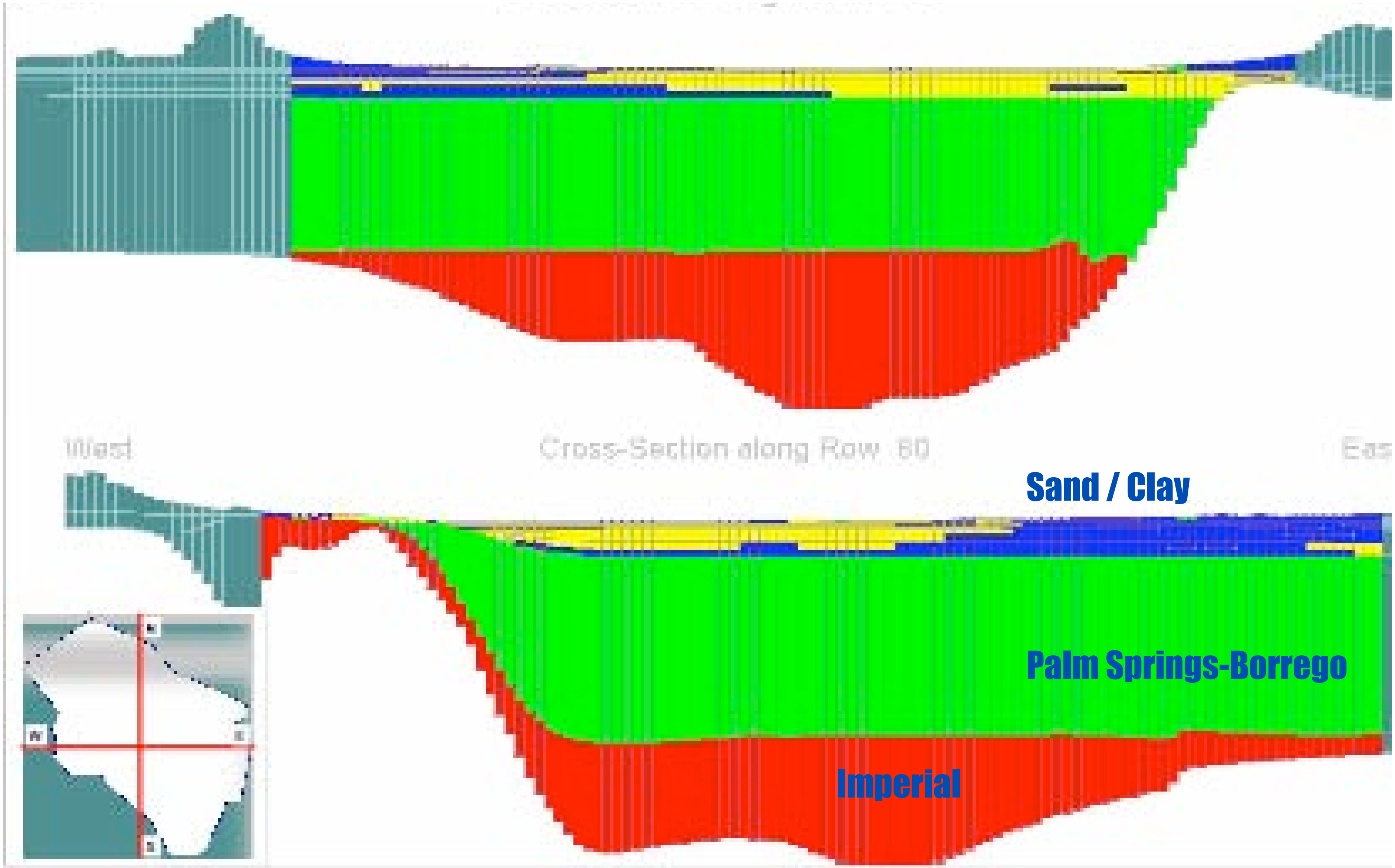


- Full depth of basin, but with maximum resolution in shallower sediment zone
- Hydrostratigraphy developed from database products
- Interpretation of isotope results to be incorporated in calibration process
- Applications can focus on fate of AAC water loss, impacts of AAC lining, production scenarios in West Mesa
- Modflow Vistas platform

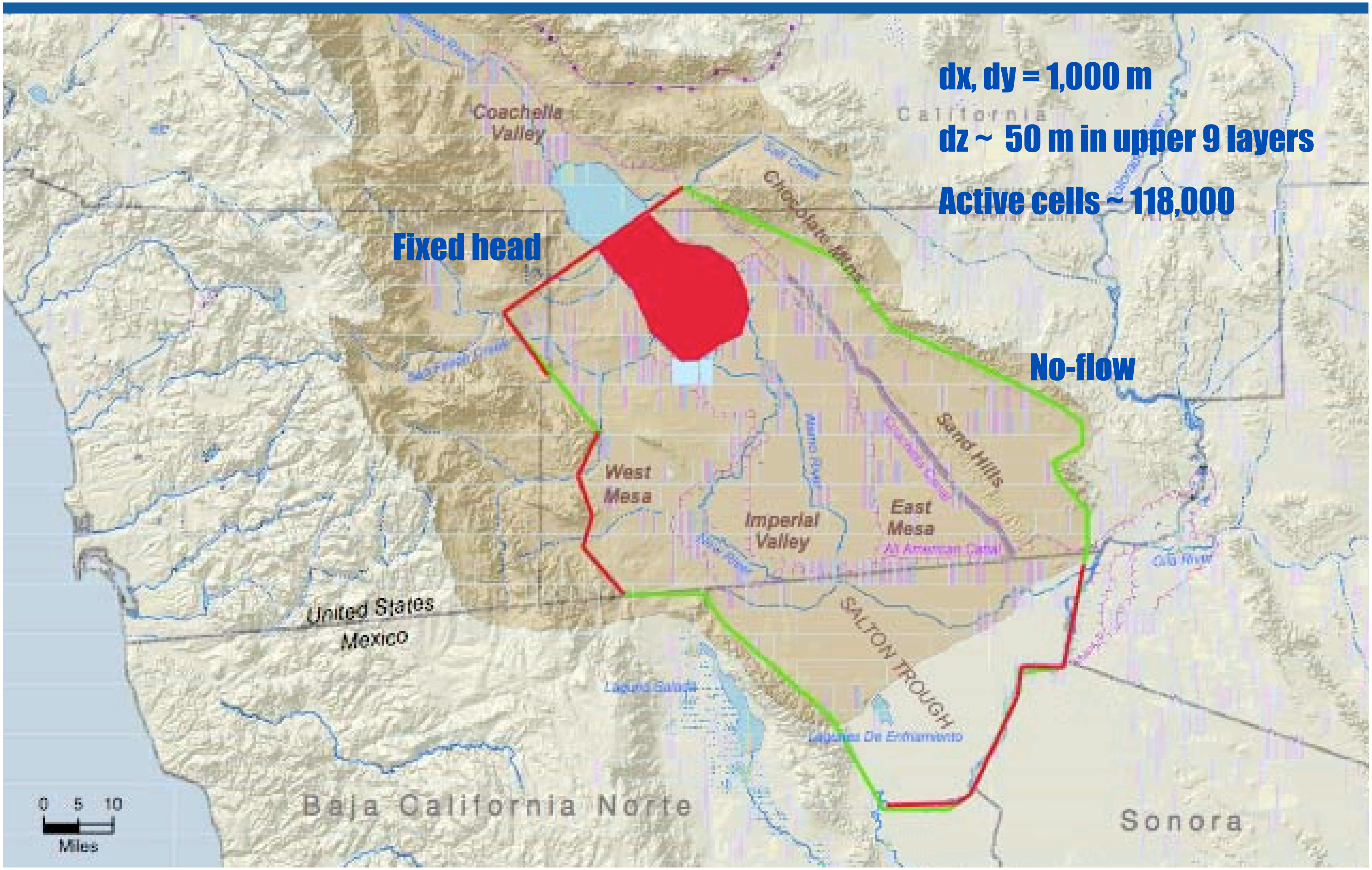
Higher resolution in shallow system used to delineate clay and sandy structures



Material assignments in model cross sections

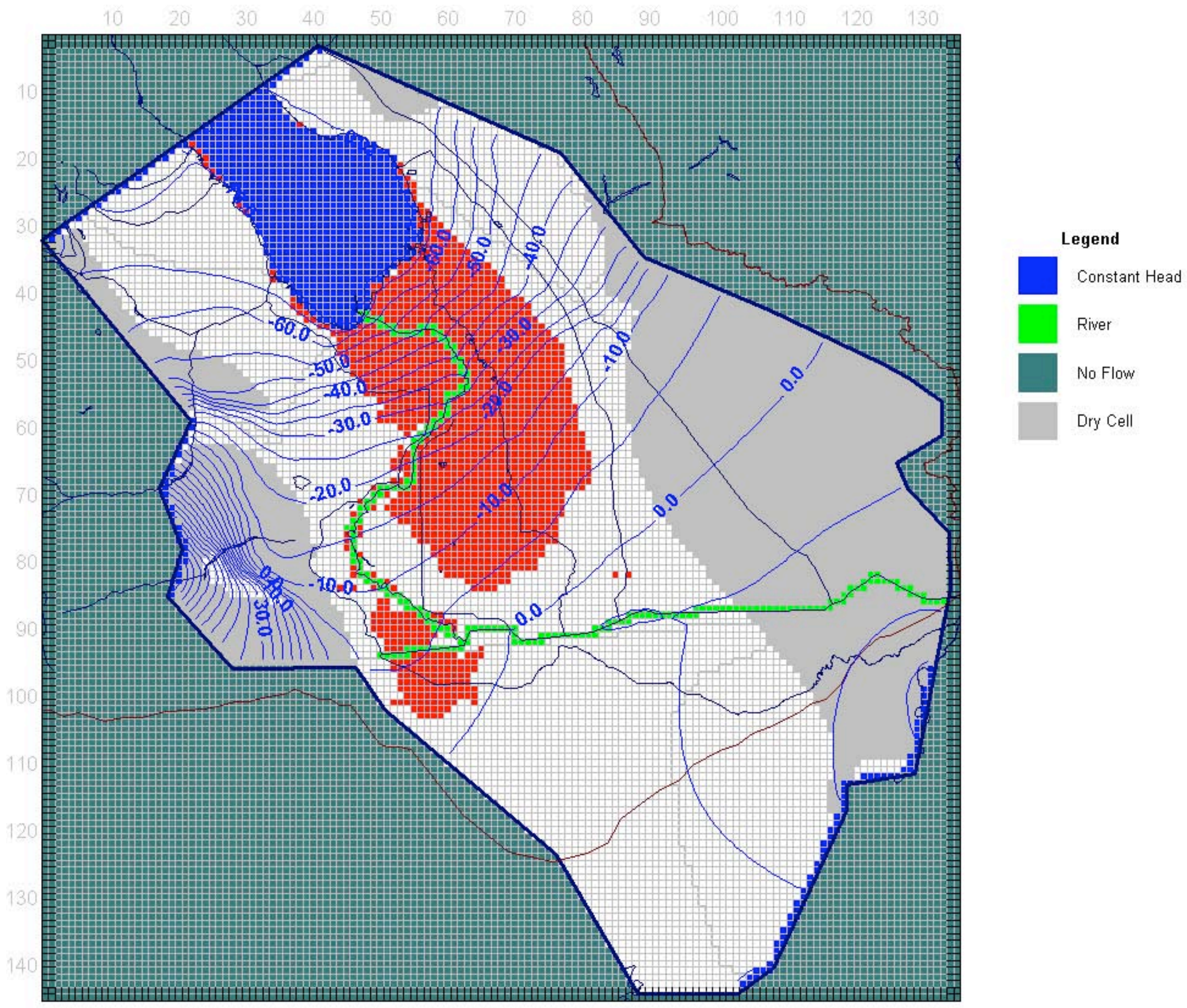


Approximate boundary conditions



Initial (uncalibrated) solutions sensitive to surface recharge assignment

- Flooding prevalent, but canal drainage options not implemented
- Tile drain processes difficult to implement and distinguish from other recharge as water levels very shallow



Working Towards a Calibrated and Tested Model

- Refinement of conditions specified along bottom and perimeter boundaries
- Improved specification of well production activities, both in the US and in Mexico, using individual wells when able
- Improved specification of aquifer recharge rates from irrigation losses, canal leakage, and precipitation, and evapotranspiration processes (including linking a surface runoff model)
- Development and implementation of calibration strategies to better estimate hydrologic parameters (e.g., PEST)

Working Towards a Calibrated and Tested Model

- Improved grid design, including use of greater resolution in important areas such as the canal areas or East Mesa; addition of refined drainage networks and channel elements into the model, and/or use of transient analyses to examine seasonal or shorter-term variations in groundwater flow and recharge behavior
- Further analyses of groundwater quality, age, and source or travel time indicators (e.g., Figure 6.10), their reconciliation with corresponding model predictions of groundwater quality, age, and source, and their role, influence, and connection to water quality in the Salton Sea proper

Working Towards a Calibrated and Tested Model

- Initiation of planning studies that address sustainable water production opportunities in the West Mesa and San Felipe Creek watershed areas and potential future aquifer storage and recovery alternatives in the East Mesa
- Development of additional analyses and calibration studies of the deeper hydrologic system and its interactions with, or affect upon, the shallower aquifer system.

Summary

- LLNL and USBR working towards development of groundwater availability assessment in the Salton Sea Basin
- "Availability" relates specifically to the **volume, producibility, quality, and renewability** of groundwater in the entire basin
- The project includes elements related to **Integrated Database Development, Isotopic Characterization,** and **Groundwater Modeling**
- Project seeks to provide management resources for renewed interest in groundwater in the basin

Findings and Conclusions

- **Significant new production** of groundwater needs to be sustainable: balanced by existing or potential new sources of recharge
- **Coachella Valley**: Increased production aided by ASR projects that can yield over 200,000 AF/y
- **Imperial Valley:** Increased production opportunities in West Mesa and ASR options in East Mesa (or elsewhere)
  - Renewable groundwater in West Mesa limited by natural recharge in the range of 2,000 to 60,000 AF/y
  - ASR in East Mesa possible, but further refinement of historical losses suggested
- **Deeper system:** Outside of quality and producibility issues, recharge scenarios not well defined; subsidence issues remain

Recommendations

- **Continued groundwater model development, calibration, and application** along lines described earlier to better define limits and scope of new production opportunities
- **Additional isotopic sampling** in East Mesa through installation of a better network of multilevel wells
- **New modeling studies of precipitation, runoff, and evapotranspiration** along the western basin perimeter to better refine recharge and renewability limits
- **Maintain, improve, and expand** the literature and water resource databases
- **Further evaluation** of the deeper aquifer flow system